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Contents

Garnet Evidence in Adirondack Petrogeny. *By* S. BENEDICT LEVIN 156
Nuclear Cytology of Fungi. *By* EDWARD DELAMATER 162
Psychological Principles of the Visual Motor Gestalt Test. *By* LAURETTA BENDER 164
The Tree of Culture. *By* RALPH LINTON 171
A Dissipation Mechanism in Gas Flows and Similar Physical Systems. *By* PAUL LIEBER 175
Conference: Development and Uses of Antimetabolites. 182
New Members 183

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GARNET EVIDENCE IN ADIRONDACK PETROGENY

By S. BENEDICT LEVIN*

It is probably fair to say that no one investigator has acquainted himself personally with the entire Adirondack province, and certainly not with all aspects of Adirondack petrology. This situation stems not only from the restrictions imposed by the geographic magnitude of the province, the roughness of its terrain, and the great diversity of features which it displays, but also from that selective blindness which, perhaps unavoidably, comes with specialization in scientific endeavor.

Under the circumstances, it is not surprising that, out of the more-or-less specialized investigations of several workers, there have emerged almost as many conflicting theories of Adirondack petrogeny; or that some of the views based largely on one kind of evidence are not in accord with those based on another kind of evidence. Yet, paradoxically, the only solution (for the present at least) is more of that specialized research, for each new batch of correlated data helps to resolve some of the conflict and make the overall picture more clear and coherent.

The need for data on Adirondack minerals. Considerable attention has been given, in the Adirondacks, to field mapping; to theoretical considerations of the physical geochemistry of anorthosite petrogeny; to the structural elements of the igneous rocks; to their bulk chemical composition; to the petrography of igneous and metamorphic facies; to certain of the mineral deposits; and to a few other problems of a special nature. There is, however, a great need for chemical and physical data on the constituent minerals of the igneous rocks, and the compositional variation of these minerals in different igneous and metamorphic facies. This is especially true because of the significant role which igneous and metamorphic differentiation played in the petrogenetic history of Adirondack rock suites, and it is evident from the literature that the solution of a number of very fundamental problems has been delayed or misdirected for lack of data on certain constituent minerals of diagnostic value.

In the category of significant constituents for which data are needed, one should include especially the plagioclase feldspars, the pyroxenes, the amphiboles, and the garnets. The present discussion deals with some of the data derived from a partial study of the garnets associated with the anorthosite-gabbro series, and with the bearing of this evidence on certain aspects of Adirondack petrogeny.

Garnet as a diagnostic mineral in the Adirondacks. The potential usefulness of garnet as a diagnostic mineral in the Adirondack province is based upon its extensive occurrence, its compositional range, its response to chemical and physical environment, and its amenability to rapid physical analysis.

(1) The diagnostic value of Adirondack garnet rests in the first instance on its widespread occurrence, both areally and in the variety of facies in which it is found. Garnet is prominent, and locally abundant, in much of the eastern two thirds of the province. It occurs in varietal and hybrid facies of anorthosite, gabbro, syenite, granite, and mixed Grenville gneisses. It is found in association with primary magmatic minerals and textures as well as in wholly metamorphic settings.

(2) The ability of the large-celled crystal lattice of garnet to tolerate a considerable and two-fold variation in composition enhances its usefulness as a diagnostic mineral. In its 11.5 to 12 Angstrom cubic unit cell are: 24 lattice positions, which may be occupied

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at random by divalent cations having radii of the order of .75 to 1.00 Angstrom unit, including especially Mg, Fe, Mn, and Ca; and 16 positions, which may be occupied by trivalent cations in the radius range of approximately .5 to .7 Angstrom units, including especially Al, Cr, and Fe, and possibly Mn. Of the 16 or more combinations or "molecules" theoretically possible by these variations, five occur prominently in Adirondack garnets. These are the Mg-Al (pyrope), the Fe-Al (almandite), the Mn-Al (spessartite), the Ca-Al (grossularite), and the Ca-Fe^{3+} (andradite) combinations, each occurring in solid solution with the others.

(3) Garnet, in its formation, is sensitive to, and ultimately reflects in its composition, the effective chemical environment at the time and place of its crystallization. It is for this reason that the structural tolerance of the garnet lattice for different ions is of diagnostic significance in relating garnets from different facies of a seriatal consanguineous group or in comparing garnets from genetically unrelated facies. In addition to this chemical response, garnet, in many instances, reflects in its textural habit (size and morphology) a response to the physical environment. This is evidently related to its strong force of crystallization.

(4) Because garnet is especially amenable to relatively rapid and accurate physical analysis, it becomes feasible to analyze large numbers of samples as well as samples available only in very minute amounts. By the measurement of index of refraction, specific gravity, and lattice constant, it is possible to calculate composition in terms of 4 component molecules, and, by the additional colorimetric determination of Mn, the fifth molecule may be determined. The five "molecules" mentioned above account for over 99 per cent of any garnet specimen in the Adirondacks.

Garnet in the anorthosite-gabbro series, southeastern Adirondacks. The southeastern Adirondacks is a particularly favorable area for the study of garnet occurrence, habit, compositional variation, and genesis, because of the abundant development there of garnet in, or associated with, members of the anorthosite-gabbro series. Within this area, the garnet deposits of the Gore Mountain-Thirteenth Lake district are especially instructive genetically, and none more so than the famous Barton deposit on the north slope of Gore Mountain. A study of this, and of many other deposits which are associated with anorthosite-gabbro facies, provides a fairly complete picture of the formation of garnet in different settings and of the influence of variations in such factors as the gabbroic versus anorthositic character of the host facies, the degree of metamorphic intensity, etc. The historical picture thus obtained is summarized in the following paragraphs.

Summary of garnet genesis in anorthosite-gabbro series. The anorthosite and gabbro are gradationally related consanguineous products of magmatic differentiation by the segregation of plagioclase crystals in a common magma. The tightly packed crystal clusters became immobile anorthosite masses, and in these the intergranular circulation of end-stage endogenous solutions was at a minimum. The loosely packed clusters (pre-gabbro) contained more interstitial fluid, exhibited intrusive mobility, and were eventually immobilized by the interstitial crystallization of augite. In these gabbroic masses, the intergranular circulation of end-stage (deuteric) solutions was considerable, and the products of the reactions between these solutions and the primary minerals are very much in evidence. The most prominent of these products was corona garnet, developed on a microscopic scale by metasomatic replacement in the peripheral portions of primary plagioclase crystals. Corona garnet was extensively developed in gabbro, less so in gabbroic-anorthosite, and only very locally developed in anorthosite proper. Common congenetic associates of the corona garnet are hornblende and some biotite. As the final product of the deuteric residual solution, grains of ilmenite-magnetite, with or without spinel, were deposited.

In the subsequent regional and contact metamorphism associated with the rise and intrusion of the magmas of the syenite-granite series, the small bodies of gabbro and anorthosite (and the borders of large bodies) were more or less converted by recrystallization and reconstitution into granoblastic metagabbro and meta-anorthosite. In the least affected portions of these bodies, corona garnet (where originally present) survives, together with the primary ophitic texture and primary minerals. But in the more intensely metamorphosed portions, the originally disseminated corona garnet was condensed, *i.e.*, recrystallized into individuals of progressively more equant and euhedral morphology and larger size, the extremely large sizes being attained only along contacts representing loci of most intense contact metamorphism. Obviously, the localization of poikiloblastic and porphyroblastic garnet was controlled, too, by the prior distribution of corona garnet.

The localization of garnet deposits of anorthosite-gabbro derivation, along (or near) the contacts of syenite against those facies, is confirmed by numerous examples in the southeastern Adirondacks. This is especially true of the most advanced garnet type, that is, the giant, hornblende-rimmed garnets of the Barton deposit, the Humphrey Mountain deposit, and the Crehore deposit. It has been suggested by Buddington (1939) that this localization is due to the more favorable conditions found where rocks of different kinds are in contact, and that all the garnet types involved (including the corona garnet) are post-syenite in age. In my opinion, the localization noted is not incidental to the juxtaposition of different rock types, but is directly and genetically due to the locally intense metamorphic influence of the syenite magma, in consequence of which the recrystallization growth of garnet in the anorthosite-gabbro facies was promoted.

Support for the view here advocated is found in the local occurrences of syenite-gabbro and syenite-anorthosite hybrid facies, in which there occurs xenocrystic garnet having the same habit and composition as its counterpart in the unassimilated gabbro and anorthosite. Petrographic mineralogic traverses disclose completely gradational transitions from normal garnet-free syenite into garnetiferous hybrid facies. It is evident, too, that the assimilative process was selective. Except locally, where some plagioclase crystals survived as xenocrysts, the plagioclase of the affected anorthosite-gabbro facies was largely assimilated and subsequently co-crystallized with the potential feldspar of the syenite magma. But the garnet and the hornblende already formed in the metagabbro or meta-anorthosite, prior to hybridization, were not assimilated. They survive in the hybrid as unresorbed garnet xenocrysts and irregular xenolithic masses of coarse, black hornblende. Because of this selective character of the assimilation, the more hornblendic, less feldspathic (i.e., the gabbroic) facies were less amenable to hybridization than were the less hornblendic, more feldspathic facies (i.e., anorthosite).

Thus, hybridization was restricted to narrow peripheral portions of the gabbroic masses. While small gabbroic bodies wholly enclosed in syenite retained their identity in spite of reconstitution into coarse, hornblendic, garnetiferous metagabbro, some small or thin bodies of anorthosite suffered thorough-going hybridization, and were thereby converted into phantom xenoliths of hybrid character, with indefinite borders, transitional into the syenitic country rock.

In these syenitic hybrids, the amount and habit of the garnet present depend upon the original character of the hybridized facies and the stage of metamorphic garnet growth attained prior to hybridization. On this basis, two types of garnet ore may be distinguished in the deposits of anorthosite-gabbro derivation: (1) *Dark ore*, which consists of garnet porphyroblasts set in a richly hornblendic matrix. This type is simply a coarse metagabbro. (2) *Light ore*, which consists of garnet porphyroblasts in a highly feldspathic matrix. This type may

be either a normal meta-anorthosite, originally of somewhat gabbroic character, or a syenitic hybrid facies of the type already described. The occurrence of both types may be illustrated briefly by examples from actual deposits.

The *Barton deposit* is the world's largest producer of abrasive garnet, and is well known for its spectacularly large hornblende-rimmed garnets. The deposit, containing about 11 per cent of garnet, is an elgonate body several hundred feet wide, over a mile long, and essentially coextensive with the intrusive contact between the regional quartz pyroxene syenite (on the south) and a body of gabbro (on the north). The gabbro is part of an anorthosite-gabbro outlier, and smaller xenoliths of anorthosite occur elsewhere in the surrounding syenitic country rock.

The bulk of the deposit is of the dark ore (metagabbro) type, containing large garnets, one to thirty (but mostly three to ten) inches in diameter and individually enclosed in a shell or rim of coarse black hornblende. A minor part of the deposit is the narrow zone of (hybrid) light ore found along the southern edge, *i.e.* on the syenite side. The light ore bears an intrusive relationship to the dark ore, and contains xenolithic masses of the hornblende and a variable percentage of porphyroblastic garnet xenocrysts one to three inches in diameter. The syenite at a short distance from the contact contains no garnet. But, in traversing northward from the deposit into the core of the gabbro body, the following completely gradational sequence is observed: (1) Dark ore, a very coarse granoblastic metagabbro, with large spherical to euhedral, hornblende-rimmed garnets (XH type). (2) A zone of coarse metagabbro with rimless garnet porphyroblasts (X type) up to about one inch diameter and quite equant in shape. (3) A zone of metagabbro with only occasional relics of the primary ophitic texture and mineral assemblage; in the dominant reconstituted portion, an abundance of millimeter-sized, very irregular, poikiloblasts of garnet (P type); in the relic portions of primary character, microscopic corona garnet (C type). (4) The ophitic gabbro, primary in all respects, except for the abundant development (up to 25 per cent) of corona garnet, C type, in the peripheral zone of the plagioclase crystals. The four textural types of garnet correspond closely in composition: all are predominantly pyrope-almandite, with only about 15 to 20 per cent of lime garnet.

As already indicated, the four types C, P, X, XH, are here interpreted as constituting a genetically related series in which the C type (which is associated only with the primary minerals and textures) is the parental type from which the others were sequentially derived by recrystallization under conditions of progressively greater metamorphic intensity. The XH garnets are not different genetically from the other (smaller, rimless) porphyroblasts, except that, in growing to such extraordinary size in a matrix so rich in hornblende, they displaced the hornblende, which accumulated around the growing garnet to form the rim.

The *Humphrey Mountain deposit*, on Humphrey Mountain along the western edge of the Thirteenth Lake quadrangle, is very similar, in setting and features, to the Barton deposit, except that no light ore zone was noted there. The deposit is of dark ore (metagabbro) type, and the garnets reached the XH stage of growth, although none larger than about eight inches in diameter was observed. The *Ruby Mountain* deposits, north of Thirteenth Lake, are examples of metagabbroic xenoliths in syenite. The garnets are porphyroblasts an inch or two in diameter.

The *Hooper deposit*, one mile east of Thirteenth Lake, is a striking example of the light ore type of hybrid facies. The deposit is a foliated feldspathic rock in which the foliation is brought out by streaks of hornblende and spherical, rimless porphyroblasts of garnet about an inch in diameter. But the matrix feldspar is not the microperthite of the surrounding syenite. It is a plagioclase, corresponding to

that in some of the light ore hybrid at Gore Mountain. The garnets are pyrope-almandite with 15 to 20 per cent lime garnet. The deposit is interpreted as a syenitic hybrid of gabbroic anorthosite, a phantom xenolith peripherally gradational into the surrounding syenite.

Primary foliated garnetiferous anorthosite, or meta-anorthosite? A considerable part of Balk's (1931–32) structural evidence for his theory of petrogenesis of Adirondack anorthosite and gabbro hinges upon his interpretation of foliated garnetiferous anorthosite as being a primary facies. That is, on finding garnet individuals, a prominent constituent (together with hornblende) of the dark streaks and lenticles which mark the foliation of border facies anorthosite, he regarded such garnet as an early magmatic mineral which had become involved in the development of magmatic flowage foliation.

If the conclusions which I have reached concerning garnet genesis in anorthosite and gabbro are correct, it would seem that much of Balk's structural evidence is in need of re-examination. For, in the foliated meta-anorthosite at Gore Mountain, one finds the same kind of garnet occurrence as that with which Balk dealt. But, in this area, the evidence of relic ophitic portions of the anorthosite, with corona garnet, and the evidence of transitional features, indicate that the garnets are metamorphic porphyroblasts rather than phenocrysts, and that the foliated, granoblastic, garnetiferous (meta) anorthosite is the product of metamorphic recrystallization from originally ophitic, partly protoclastic, gabbroic anorthosite.

Skarn, or gabbro in statu nascendi, or meta-anorthosite? Another fundamental problem, closely related to the one just mentioned, concerns the genetic interpretation of the streaks, schliere, or lenses of dark minerals (chiefly, garnet and hornblende) which are so prominent in the foliated anorthosite near Schroon River, within the southeastern border of the massif. Balk (1931) interpreted these dark schliere as the products of flow segregation of primary magmatic minerals, and regarded them—the dark schliere—as illustrative of gabbros in the initial stage of formation. Buddington (1939) interpreted the same features as shreds of Grenville skarn.

In the hope that garnet data might help to resolve the problem, I visited the same area, examined the host rock, and later analyzed some of the garnet. I found the host rock to be a granoblastic meta-anorthosite similar to that which occurs in the Gore Mountain area, and the garnet to be similar in habit and composition to the P and X type garnet of the Gore Mountain meta-anorthosite. The garnet compositional ratios found were: $Mg_{12}Fe_{53}Mn_1Ca_{34}$ at Gore Mt.; $Mg_8Fe_{53}Mn_1Ca_{38}$ at Schroon River. Since, in skarn garnet, Ca almost invariably exceeds 85 mol per cent, while Mg is either absent or very low, and since these conditions are met by all Adirondack garnet of definite skarn origin reported thus far, it is a fair preliminary inference that the Schroon River mineral is more likely a normal meta-anorthosite garnet than a skarn garnet. Here again, if the interpretation of the garnet evidence is correct, then the earlier explanations should be re-examined.

Garnetiferous gabbro-amphibolite, or meta-gabbro? Consistent with his views of gabbro genesis, Balk referred to the lenses or larger masses of dark minerals in anorthosite and in syenite as gabbro-amphibolites, and he regarded them as flow segregations of primary magmatic minerals. Thus, he interpreted the Crehore garnet deposit, near Casey Mtn. in the southern part of the Newcomb quadrangle, as a primary garnetiferous gabbro-amphibolite in syenite. Where larger gabbroic bodies have amphibolitic border facies and massive ophitic pyroxenic core facies, he regarded the former as primary magmatic and the latter as secondary, the result of recrystallization of original gabbro-amphibolite.

If these views were applied to the Barton deposit and to the gabbro body of which it is a part, it would be necessary to regard the

garnet deposit, and the giant garnets, as magmatic. Now the garnets are so large and so superior in morphology, when compared with their mineral associates, that, as magmatic phases, they would surely have been among the earliest to form. Also, since they are at least half again as dense as the densest magma in which they might have grown, they should be gravitationally segregated. But they are not. In fact, the larger the garnets, the more distantly they are spaced from each other.

Moreover, an analytical traverse across a diameter of one of the larger Barton garnets (19 inches) discloses that there is a slight but distinct decrease in Fe/Mg ratio from core toward periphery. This is the opposite of what is to be expected in a zoned magmatic ferromagnesian.

The garnet evidence here is in accord with a host of other data pointing to the garnetiferous amphibolitic facies as the metagabbro and to the ophitic pyroxenic facies as the primary gabbro.

Corona garnet and the ilmenite-magnetite deposits. As a final example of the bearing of garnet evidence on Adirondack petrogenetic problems it is of interest to note the prominent occurrence of garnet in association with the ilmenite-magnetite ores of the Sanford Lake district. In that area, large masses of ilmenite-magnetite occur conformably in gabbro and disconformably in anorthosite. Wherever xenolithic anorthosite or plagioclase crystals occur in the ore, and wherever veinlets or dikelets of ore cut the anorthosite, there is a zone of "reaction" minerals between the ore and the anorthosite or plagioclase. Garnet is the most common constituent of the reaction zone, hornblende the next most common.

The garnet, found locally as the major or sole constituent of zones several inches thick, was tentatively reported (Stephenson, 1945) as having the compositional ratio $Fe_{10}Ca_{90}$, corresponding to skarn garnet. Since such a composition would be quite unusual in that setting, and quite difficult to reconcile with the conclusions reached with respect to the origin of the Fe-Ti ore, I took the occasion to verify the garnet composition by physical analysis of a typical specimen. The results are interesting and, I believe, rather significant; for they indicate a composition (approximately $Mg_{42}Fe_{44}Ca_{14}$) almost identical with that of the microscopic corona garnet of the Gore Mtn. gabbro. It will be recalled that the chemical and petrographic evidence at Gore Mtn. indicate a direct genetic relationship between the widely disseminated micrograins of ilmenite-magnetite and the microscopic corona garnet with which they are associated. The conclusion reached was that late-stage, endogenous (*i.e.* deuteric) solutions, moving through (or trapped in) a multitude of micro-channels in the gabbro, first produced corona garnet by reaction with the plagioclase, and finally precipitated the grains of ilmenite-magnetite. From a quite different array of evidence, Stephenson (1945) concluded that the massive ilmenite-magnetite deposits at Sanford Lake are the products of crystallization from a late-stage deuteric residuum. The correspondence between the Gore Mtn. microcorona garnet and the Sanford Lake garnet zones, in terms of mode of occurrence, mineral associates, and composition, thus tends to provide mutual confirmation for the interpretations reached independently in the two separate areas. On the basis of such evidence, one is probably correct in regarding the micro-disseminated ilmenite-magnetite of Adirondack gabbro as the genetic counterpart of the ilmenite-magnetite which, at Sanford Lake, became concentrated into very large masses. That relationship, which has been assumed by some on an *a priori* basis, although supporting evidence was lacking, is of direct and timely bearing on the genesis of titanium deposits in anorthosite-gabbro.

The examples cited serve to illustrate the useful potentialities of correlated garnet data in helping to resolve certain apparent conflicts in Adirondack petrogeny and in facilitating the correlation of independently developed evidence of various kinds. Obviously, there are inherent dangers in apply-

ing to one part of the province, by extrapolation, the interpretations based upon evidence derived from another locality. But, since the same fundamental processes were probably operative throughout the province, differing from one locality to another only in degree, it is obvious, too, that the evidence derived from detailed studies of the essential mineral phases of the igneous and meta-igneous rocks is of prime importance in solving the basic petrogenetic problems of the entire province.

Note.—A more detailed and documented presentation of the evidence and arguments bearing on the genesis of some Adirondack garnet deposits has been prepared by the author for publication by the Geological Society of America.

*DIVISION OF MYCOLOGY**

NUCLEAR CYTOLOGY OF FUNGI

By EDWARD D. DeLAMATER†

The nuclear activity of various fungi has long been observed in the work of R. A. Harper,[1] Dangeard,[2] Juel,[3] and others,[4] who demonstrated beyond the question of a doubt that typical mitosis occurred in all of the fungi observed. That these nuclear activities were comparable to, if not identical with, what occurs in higher organisms with larger cells, could not be questioned. However, because of the size of the nuclei of these organisms, the limits imposed by the microscopical resolution obtainable with white light, and the difficulties encountered because of inadequate definition of nuclear structures with non-specific staining methods, little more could be ascertained. It has not been until the recent work of McClintock[5] on the Neurospora in which she used the aceto-orcein method, and the work of Robinow and DeLamater[7, 8] who developed special techniques in which the ribose nucleic acids in the cytoplasm were removed by acid hydrolysis, that a clear-cut picture of the nuclear activity of these minute nuclei and their contained chromosomes could be observed. The elimination of the reducing substances which occur normally in the cytoplasm and obscure the nuclei when they are stained with such basic dyes as hematoxylon, permits future clarification of the whole problem.

The work of Lindsay Olive[9] and that of DeLamater,[10] presented at the American Mycological Meetings, 1948, both demonstrated that there is an elongation and contraction of the chromosomes of fungi during the nuclear cycle. It seems likely that the so-called elongation and contraction of the chromosomes corresponds to the coiling and uncoiling of the chromosomes described in higher forms. In both studies, photographic evidence was presented which showed what was described as beading of the chromosomal threads. This beading appears to correspond to the euchromatin and heterochromatin banding of higher organisms, although this needs further clarification.

The vegetative nuclear cycle of *Blastomyces dermatitidis* has been described in detail and photographed by DeLamater.[11] There is a rather remarkable correspondence between the observations made on this organism and those made by the same author on the diploid vegetative phase of *Saccharomyces ceravisiae.*[10] However, there are one or two points of difference worthy of note.

There are four relatively easily identifiable chromosomes in the diploid phase of *Saccharomyces*, two paired elongated chromosomes, and two paired round chromosomes in the condensed phase. Immediately following telephase, the nucleus enlarges and the chromosomes elongate (uncoil?) into long, delicate, beaded threads

* The Section of Biology held a meeting on February 14, 1948, at which Doctor Morris H. Harnly, Department of Biology, New York University, N. Y., presented a paper entitled "*A Physiological Interpretation of the Effect of Temperature upon Development*," illustrated with lantern slides. When this paper is received it will be published in the TRANSACTIONS.

† Department of Dermatology and Syphilology, University of Pennsylvania, Philadelphia, Pa. This paper, illustrated with lantern slides, was presented at the meeting of the Division on February 25, 1949.

which lie irregularly in the nucleus against the nuclear membrane.

In the expanded, enlarged, interphase nucleus, the nucleus itself may obtain a size of about two microns, and the chromosomes may obtain a length of from two to four microns or longer, with diameters of 0.25–0.35 microns. As the nucleus progresses toward the next division, the chromosomes contract (coil?) to one side of the nucleus and become very dense. At about this time, a centriole appears on the nuclear membrane opposite the condensed chromosomal mass.[12] This centriole then divides in two, and each daughter centriole moves or migrates to opposite sides of the nucleus. These centrioles are approximately 0.25 microns. When the centrioles or polar bodies lie at opposite sides of the nucleus, the chromosomes lie transversely between them, forming a typical spindle. They then proceed to divide and migrate to the two poles. At the time of division, the distinct chromosomal masses become hazy and difficult to stain, and, as the chromosomes separate, the mass appears to stretch out and pull apart like a piece of taffy. Except in very exceptional and rare preparations, it is impossible with present methods and present magnifications to define the inherent structure within the separating chromosomes at this stage. It does appear, however, to be a valid interpretation that the chromosomes at this stage undergo a second period of elongation or uncoiling and that they are actively stretched as they pull (are pulled?) apart and proceed to the poles. It is this phase of the division, the anaphase-telephase stage, which has been so accurately and repeatedly described by Guillermond,[13] and it is this phase which Guillermond interpreted until recently as evidence for an amitotic nuclear division in the yeasts. Once the chromosomes have arrived at the poles, they again condense or contract into discrete masses, the centriole or polar body disappears, the nucleus again enlarges, and the chromosomes again expand to repeat the cycle as described.

In *Blastomyces*, which is a multinucleate cell, the new buds appear to form independently of nuclear activity unless their development is related to the nucleus-cytoplasm ratio. The nuclei migrate without division during their interphase, or vegetative phase, into the new bud.[11] In *Saccharomyces*, which is a uninucleate cell, the bud forms apparently independently of the stage of the nuclear division and, during the interphase or early prophase, the axis of the nuclear division may occur in any direction and need not be related, apparently, to the point of origin of the bud. Cases have been observed in which the axis of the nuclear division points directly into the bud; others have been observed in which the axis of the nuclear division occurs in the longitudinal axis of the parent cell; and still others have been observed in which the axis of the nuclear division occurs at any angle to the origin of the bud. It has been interesting to observe that, during the anaphase-telephase stage of the division, the daughter nuclear mass which is proceeding into the bud can become contorted and twisted as it turns corners, *etc.*, to get into the bud.

Definition of what constitutes the nucleus of a yeast cell has come only with the development of new methods. Lindegren,[14] recently considered the nucleus to be the vacuole of the yeast cell, and the object which we here describe as the nucleus to be the centriole. The chromosomes of Lindegren are intra-vacuolar granules, probably consisting of ribosenucleic acid. The granules which Lindegren considers to be chromosomes are eliminated by weak acid hydrolysis[7, 8, 16] and, contrary to the observations of Rafalko,[15] do not stain with the feulgan stain. The only object within the cell which takes the feulgan stain is the body at the side of the cell vacuole, which is here described as the nucleus. It has been possible to confirm in detail with the feulgan stain the observations recorded here, using the aldehyde-mordanted basic fuchsin method, and to confirm the observations of Winge[17] that this is the only feulgan positive body in the cell.

It seems warranted to assume (1) that the nucleus of *Saccharomyces* has now been

defined; (2) that chromosomes of a recognizable shape and size have been observed; (3) that the vegetative nuclear cycle conforms to the general pattern characteristic of higher organisms; (4) that a centriole and polar bodies are constantly present in these divisions; (5) that a typical mitotic spindle is produced during the division of the nucleus; and (6) that there are two periods of chromosomal elongation and contraction, or coiling and uncoiling, during the vegetative nuclear cycle.

It is hoped that, in the near future, the complete nuclear cytology of nuclear fusion and mitosis of *Saccharomyces* can be presented with photographs.

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SECTION OF PSYCHOLOGY

PSYCHOLOGICAL PRINCIPLES OF THE VISUAL MOTOR GESTALT TEST

By LAURETTA BENDER*

In contrast to association psychology, gestalt psychology states that we do not perceive parts of the stimuli and build them up into images, but that we perceive the whole or total quality of the image. The organization of the stimuli into the image is based upon laws of perception which include proximity, similarity, direction, and inclusiveness of the stimuli. The basic concept is that the whole is more than the sum of its parts. This perceptual experience is called a gestalt or configuration or pattern. Organized units or structuralized configurations are the primary forms of biological reactions. In the sensory field, these gestalten correspond to the configurations of the stimulating world. This is the static concept of the classical gestalt psychologists (Wertheimer, Koffka and Koehler†). It fails to account for drives and tendencies of human conduct, growth, retardation in growth, or regression.

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† For references to the literature see Bibliography. [1, 2]

Paul Schilder emphasized the importance of dynamic concepts in gestalt psychology. He stated that there was not only a "Gestalt" but a "Gestaltung," meaning that the organism in the act of perceiving always adds something new to the experienced perception. He said, in the introduction to my monograph, that "the organism does not react to single local stimuli by single responses but by a total process which is the response of the whole organism to the total situation."

The organism has a "gestalt function" which is defined as that function of the integrative organism whereby it responds to a given constellation of stimuli as a whole, the response being a constellation or pattern or gestalt which differs from the original stimulus pattern by the process of the integrative mechanism of the individual who experienced the perception. The whole setting of the stimulus and the whole integrative state of the organism determines the pattern of response.

We find, however, that there is an innate tendency to experience gestalten not only as wholes which are greater than their parts, but in a state of becoming (Eddington), which integrates configurations not only in space but in time. There is a tendency, not only to perceive gestalten, but to complete gestalten and to reorganize them according with principles biologically determined by the sensory motor pattern of action which may be expected to vary in different maturation or growth levels and in pathological states organically or functionally determined.

Even in deviate individuals, *i.e.*, aments or dements, the drive to experience complete gestalten and to contribute to the integration of gestalten are always present. A gestalt is always experienced, but in a more primitive form in which the whole is still greater than all its parts.

The visual motor gestalt test consists of figures (PLATE 1) taken from Wertheimer's classical studies. They are presented one at a time, to be copied by the individual or patient who is being studied.

Figure A is the introductory figure. It consists of a circle and a diamond-oriented square—touching each other on the horizontal plane. This is readily experienced as two closed figures on a background. According to Wertheimer, this configuration is recognized as two contingent figures, because each represents a "gute Gestalt" which refers to a complete, consistent, and coherent configuration or geometrical form.

Figure 1, according to Wertheimer, should be so perceived that the dots appear as a

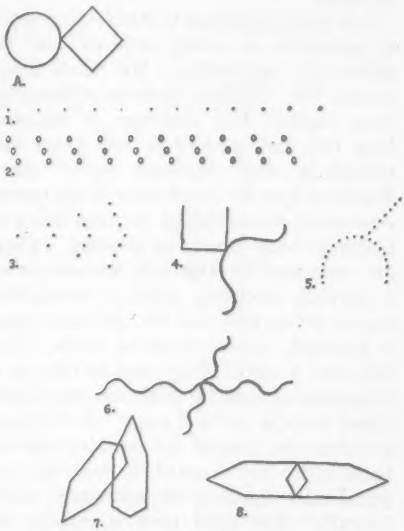

PLATE 1. Test figures adapted from Wertheimer.

horizontal series of pairs determined by the shortest distance, or with "remnants" left over at each end. This is an example of a gestalt formed on the principle of the proximity of parts.

Figure 2, according to Wertheimer, is perceived usually as a horizontal series of short, slanting lines consisting of three loops. It is also determined on the principle of proximity of parts. This is also true of Figure 3, formed by dots. Figure 4 is perceived as two units determined by the principle of continuity of geometrical

or internal organization: the open square and the bell-shaped form at the lower right hand corner. The same principle holds true for Figure 5, which is seen as an incomplete dotted circle with an upright slanting stroke. Figure 6 is seen as two sinusoidal (wavy) lines crossing each other at a slant. Figures 7 and 8 are two configurations made up of the same units, but they are rarely perceived as such, because in figure 8 the principle of continuity of geometric form prevails—which in this instance are the straight lines at the top and the bottom of the figure.

It is most important to study the genesis of perception in young children, and to follow its maturation. We have long known that children perceive differently from adults. The drawings of *children* from two and one-half to four years are scribblings that represent motor play. These are done for the pleasure of the motor expression, the scribbled pictures being a by-product and having no meaning. They are performed by large arm movements in a dextrad, clockwise whirl, or pendulum waves, if the child uses its right hand; and in sinistrad, counter-clockwise whirls, if the left hand is used. They tend to take on a differentiated form by inhibition into single closed loops or parts of loops. Patterns or gestalten are formed by combinations of these which are adapted to resemble the perceived stimulus or to represent it symbolically. The child finds it difficult to reproduce patterns, but by various motor experimentation, pictures are produced which may finally represent the pattern desired. It is easier for the child to imitate the movements of another person so that scribbling may be limited to single arm movements, to dashes, dots and zigzags. Thus, any dotted form may call forth motor behavior that produces dots, but the tendency may still persist to produce them in loop formation, masses, or series. An enclosed loop is the basis of all perceived form. There is also a tendency to perseverate any one learned (even if self-discovered) pattern wherever adaptable to other perceived figures. Direction, especially dextrad horizontal direction in the right handed child, is more important than distance or size. It is more overwhelming than Wertheimer's principles of proximity or similarity of parts. This predominance of the directional factor is probably due in part to motor features, and in part to the principle that the optic field is organized on movement. Concepts such as series and masses are more readily grasped by children than absolute number or size. Wertheimer's principle of continuity is important to the extent that it involves direction and series. His principles of 'gute Gestalt' and natural geometrical figures are important to the extent that they arise out of the primitive loop. Otherwise, the principles of gestalt, as given by Wertheimer, do not apply to the genesis of gestalt in the maturation of the child's visual motor patterns.

Rapid differentiation of form, maturing of the motor apparatus, and the capacity for object representation take place between the fourth and seventh year.

A. A. Fabian, while he was working with education disability in the problem children at Bellevue and normal children in the public schools, found that the tendency to rotate horizontally directed configuration to the vertical position is found in the normal child of pre-school and beginning-school age. It is a developmental phenomenon which is gradually corrected as the child matures, but does not disappear until he is seven or eight years old. He showed that "muscle mechanics of the arm favor movement in the vertical direction." Movement tendencies in the gestalt function also contribute. Finally, body image factors, described by Schilder as "all the perceptual experiences integrated into a schema which represents one's experiences about one's own body," influence the projected sensory experience of the developing child. Upright posture is a factor also. The close relation with the visual motor gestalt function and language development is emphasized by Fabian. Those children who show reversal tendencies in reading disabilities

may be shown in testing with the gestalt test or similar tests to persist in the tendency to verticalization of horizontal figures or to rotation of figures.

Plasticity as a feature of the very young child, which is readily recognized in the gestalt test, especially when it is viewed as a total gestalt on one sheet of paper, was not sufficiently emphasized by me in the earlier work. I have seen it more frequently in schizophrenic children and in some gestalt test material of 149 *native children* from the Chamorros and Carolinians of Saipan in the Mariana Islands, who were examined by Dr. Alice Joseph and Dr. Veronica F. Murray, under the Pacific Science Board of the National Research Council. Drs. Joseph and Murray observed that these children's gestalt drawings differed from the norms for American children, which I had published, and permitted me to study them. I observed that there was a strong drive to accomplish the task well and a high degree of conformity. At the same time, there were many indications of fluidity or plasticity or primitive trends. For example, square corners were rounded. Even so, squares and diamonds were clearly formed. There was a strong tendency to rotate figure or an accentuation of verticalization at all age levels. Dotted lines tended to increase motility and were often expressed as wavy lines. Open figures were closed. In general, there was more movement and action. Also, parts of the figures were influenced by other parts and each figure was influenced by others in the performance and by the frame work of the background. Figures were even tied to each other, and the total test tended to make an organized design. Erasures showed strong tendencies to overcome primitive tendencies for more mature and rigid patterns.

PLATE 2 are the gestalt drawings of a *defective schizophrenic* adult. They show that the more primitive sensory motor patterns are dependent on the principle of constant whirling motion. . . . in a vortex, with an associated radiating directional component with a tendency to emphasize the horizontal planes. Fixed points are difficult. There is also a tendency for dots to become loops, for straight lines to curve a little, for parallel lines to radiate toward or away from each other, and for sensory-motor patterns to revert to more primitive principles and to express movement in some way.

Experiments with *optic imagery* in four subjects showed that the inherent quality of all optic images is movement. This movement includes whirling, waving, ex-

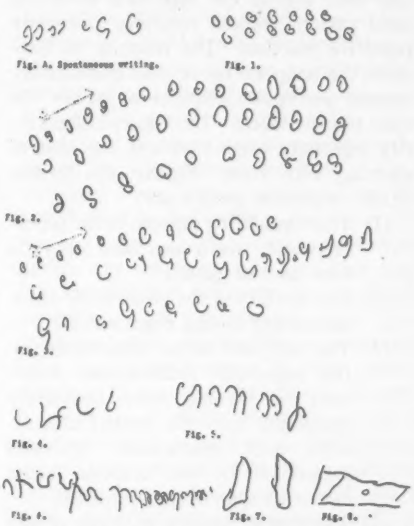

PLATE 2. Gestalt test performed by defective schizophrenic adult.

pansion, contraction, scintillation, molecular movement, *et cetera*. By these movements, all figures are reduced to their simplest form, which was a closed circle with a fixed center but no fixed periphery. A point was a center of a possible circle; a line was a direction which was most typically horizontal dextrad. All configurations actively used some one or more elementary forms of movement in order to realign themselves into a primitive quiescent form.

The use of a short time exposure of the gestalten by the *tachistoscope* lead to the

experiencing of more primitive forms. This suggests that the temporal factor is important in total experience and that the active relationship that exists between the observer and the stimulus and which creates the visual motor gestalt requires sufficient time unit for the creation, and that this temporal factor, moreover, results in a different and more mature type of gestalt experience. It seems, therefore, that one important factor in the maturation of visual motor patterns is the integration of the temporal factor into the whole situation and that this is not separable from the total pattern without resulting in a more primitive reaction. The capacity to integrate the temporal factor into immediately created perception requires a certain life span to experience. The concept of maturity rightfully carried with it the idea of ripening with time. Finally, the factors which determine gestalt are:

(1) The stimulating pattern in the physical world, which also must obey its own laws of gestalt.
(2) The motility of the visual field, which determines spatial relationships.
(3) The temporal factor determined by the sequential relationships which tend to become more intricately integrated into the spatial relationships with maturation processes determined by the temporal factor of the life span of the individual.
(4) The motor reaction patterns of the individual, and his attitudes towards and actual participation in the individually created experiences.
(5) The immediate tendency for each of these factors to be nonseparable from the others.

This test was standardized once as a *performance test* for children. Related studies with the gestalt figures convinced me that the visual-motor gestalt function is a fundamental function associated with language ability and closely associated with various functions of intelligence such as visual perception, manual motor ability, memory, temporal and spatial concepts, and organization or representation. Up to the age of four, the small child usually produces scribbles in response to gestalt figures as a stimulus. The Goodenough drawing test of a man starts with a basic mental age of three years. The standardization of gestalt maturation and function covers the ages of four to eleven, which is the age when language function, including reading and writing, are developing. Like the Goodenough, it is not valid after adolescence. The results of attempted standardization are shown in Figure 3 (PLATE 1).

The hypnotic ablation technique of Herbert Spiegel, *et al.*, at the Army Installation Center in the Mason General Hospital, corroborated the results of the standardization on children.

A man with acute transitory *aphasia* due to a thrombosis of a cerebral artery, showed regressive phenomena in motor behavior, verbal speech and visual motor gestalten. Each day he showed the same tendency to approach the problem of copying the gestalt figures in a well organized attempt, which was, however, soon frustrated by an uninhibited tendency to perseverate the units of his own response. The outstanding features in the responses were: The larger principles in the organization of the gestalt were more significant and persistent than the details, and were often exaggerated; there was a tendency to revert to more primitive reactions, such as are seen in children and mental defectives; the responses were more compact, enclosed, and energy-saving; there was an uninhibited perseveration of the unit symbol and of the preceding responses of the principles of the organization, and this tendency was likely to lead to confusion and finally to complete blocking or paralysis; recovery from the cerebral insult showed the same type of progressive integrative maturation, with episodes of sudden insight into the problem as a whole which is shown in normal developing and learning; in this recovery or relearning, the larger principles of the relationships of the gestalt appeared before the details of quality of form and

distances of space, or, in Wertheimer's terms, of proximity and similarity.

In general paresis of the insane or *dementia paralytica*, the dull lethargic types, the visual motor gestalten is reproduced with evidence of poverty of impulses and of fragmentation at artificial points in the configuration suggested by the superficial appearance rather than by the genetic gestalt principles. In the expansive types, there is a tendency to substitute letters, numbers, dashes, or the patient's own initial for parts of the configuration, while the whole figure remains fairly intact. This may be akin to confabulation. The whole figure may be disoriented on its background. The general principles of the gestalt are preserved at all times. Some change of a minor nature happens to the concept after it is correctly conceived as a whole. Early cases of *dementia paralytica* in well integrated persons, or cases in which treatment has been administered early, show certain compensatory features. There is a tendency to formalistic but impersonal perfection. Nearly always, however, there is also some telltale feature suggesting one or another type of deviation, or reversion to some primitive feature, such as the use of the closed loop or perseverations in horizontal dextrad directions. These primitive reversions are more common in cases with aphasic, agnostic or apraxic features.

The *alcoholic psychoses* are associated with deep clouding of consciousness, perceptive difficulties resulting in incompletely perceived gestalten, and motor difficulties with increased impulses to rhythmic movements. By this combination, the visual motor gestalten in copied figures are profoundly disturbed, so that the figure is reproduced incompletely and is distorted by perseverated strokes. With less clouding of consciousness, more features of disturbed motor impulses in the perseverative tendencies of the figure are produced. This is a perseveration of motor impulses or rhythmic movement and not a perseveration of form, such as is seen in the sensory aphasias. In chronic alcoholic hallucinatory states, the gestalt as a whole is well perceived, but the outlines are hazy, perhaps partly from perceptive difficulties, partly from tremulousness, and partly from the motor impulse to reiterate the line. In the confusional states, there are less marked motor difficulties, but the perceptive difficulties lead to disturbances in the integration of the parts into the whole and in the orientation of the figure on the background.

The study of the visual-motor gestalt function in *mentally defective children* shows that the problem of mental deficiency is not a simple one. If we were to assume a slow-up or simplification of the maturation process in a unified way, we would expect less differentiation, a more unified system, a stronger and simpler gestalt, such as we find in the younger normal child. This does occur in some individuals, especially among the higher-grade defectives. Even in these cases, motor control is usually better than in the normal children of the younger age. Small, energy conserving figures are the rule. The primitive loop is freely used with less motor play or experimentation. The patterns are more rigid. Individuals who are functioning as mental defectives show evidence in their gestalt drawings of more or less aphasic disturbances which are characterized by the use of a perseverated, primitive, symbolic unit; others show the dissociative phenomena characteristic of schizophrenia; still others show disturbances in impulses with a poverty of responses or hyperkinetic features, such as occur in some types of encephalitis; and, finally, others show perceptive difficulties, confusional features which may be related to focal brain pathology. Such analysis leads us to the opinion that there are multiple causes of mental defectiveness, which might be differentiated with the hope of more specific treatment, training, and prevention.

My first experience with the clinical use of the visual-motor gestalt test was with the *schizophrenic* patients at Springfield State Hospital in 1929 to 1930. (See PLATE 2.) Gestalt drawings of typical

schizophrenic patients are easily recognized by the bizarreness of the configurations produced, the frequent splitting in figures, not in such a way as to make a "gute Gestalt," and especially by showing an unusual cohesion between all the figures and an increase in movement in the figures. Attempts to use these figures as matrices for delusional ideations by ornamenting them with connecting lines, destroying the original gestalt and creating new figures, are usually noticeable. In such instances, the gestalt test really becomes a projective technique by allowing the person to be tested to project his own ideations into the test performance.

Recently, I have had more experience with *childhood schizophrenics* and have found that all their behavior, including their gestalt functioning, is characterized by a striking plasticity or fluidity due to the tendency to use old primitive responses interlocked with the more mature capacities which are expected from the maturational level of the child. There is, therefore, an excessive use of the vortical movement even with good diamond forms. A series of figures on a horizontal plane may be pulled around into a vortical figure. The boundaries of circles are uncertain and may be gone over several times. The centers of circles are uncertain. There are no points but many little circles. Angular and crossed forms are fragmented. Action cannot be readily controlled and figures are elaborated, enlarged, repeated. The total product makes a pattern itself with a great deal of fluidity based upon vortical movement. The perceptual patterns lose their boundaries and therefore their relationship to the background. There is cohesiveness between the boundaries of two objects. In this well-patterned fluid matrix, there are areas in which the pattern is broken; a part of a figure is separated from the whole and made to rotate faster; a group of small circles is separated from the whole mass. It is as though in a circular stram of rippling water, a pebble was thrown, causing a new wave movement.

In my own studies, I did not expect to find disturbances in perception or in the visual motor gestalt function in the *psychoneuroses*. However, it was often possible to evaluate severe anxiety and compulsive obsessional features, especially when they occurred as defense mechanisms in individuals with organic disorders or psychoses which threatened the integrity of the organism.

During the war, this test was used in a number of Army Installation Centers to aid in differentiating between emotional regression and the effects of organic brain injury or schizophrenia. It was also used in an effort to explore *personality dynamics*, but the results of this research are still inconclusive.

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SECTION OF ANTHROPOLOGY

THE TREE OF CULTURE

By RALPH LINTON*

Current interest in the functional and psychological approaches to culture has made the study of culture origins unfashionable. However, the writer believes that these still have real value. Whatever the functions or psychological connotations of culture traits, their form can be understood only when their origin is taken into account. The present paper is an attempt to present a brief summary of the development and differentiation of cultures in the light of our present knowledge. Much of the information which we would like to have as a basis for this is and always will be lacking, but we have enough to make possible a tentative reconstruction. Even this may be useful on the basis of Bacon's dictum that Truth can be brought out of Error more easily than out of Chaos.

The tree simile for the development and differentiation of living forms is already familiar. However, this is usually pictured as a tree of the temperate zone with a single sturdy trunk from which spring increasingly diversified branches and twigs. The tree of culture bears more resemblance to a banyan tree in which branches cross and fuse, and aerial roots, finding favorable ground, turn to trunks stronger than the parent one. The result is a miniature jungle, but one whose development can be traced step by step.

It appears from our present knowledge that culture is older than our species and may even have played a significant part in fixing certain of its characteristics. By the Middle Pleistocene, three cultures appear to have been in existence: A Large Flake culture extending across most of northern Eurasia, the Biface culture extending over southwestern Eurasia and Africa, and the Pebble Axe culture centering in southeastern Asia and extending westward to Central India and northward for a still undetermined distance. The Large Flake culture seems to have represented an adjustment to a cold environment in which a predominantly hunting economy would have been necessary. Since few of the implements belonging to this culture are themselves suited for use as weapons, one must assume that there was a considerable inventory of objects of perishable material. Whether these three old cultures were the work of different Hominoid species is not important for a reconstruction of culture history. A species able to invent and manufacture tools could hardly fail to copy the tools of another species so closely related that both had essentially the same psychological and physiological equipment.

By the time of the last glacial advance, the Large Flake and Biface cultures had fused in Western Eurasia to produce the Middle Paleolithic cultures, predominantly flake-using and hunting. The Biface cultures seem to have survived longest in Africa. The Pebble Axe cultures, on the other hand, seem to have undergone little modification, possibly reflecting the slight climatic changes in the region in which they existed. The western Paleolithic typologies are quite inapplicable to this region.

Toward the close of the Pleistocene, the Western Eurasiatic cultures show a tendency to employ an increasing number of materials, limiting each to the implements for which it was best suited. Thus bone, antler, and ivory replaced stone at many points. The apparent stagnation of culture in the Pebble Axe tradition may reflect an increasing dependence here on perishable materials, especially bamboo, which would render many types of stone implements unnecessary. Toward the close of the Upper Paleolithic, composite tools based on microliths were developed in Western Eurasia and spread to Africa where they survived, until recent times, in extreme South Africa.

By the close of the Pleistocene, *Homo*

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sapiens had spread to approximately his present limits. Outlying islands had not been reached and the northern limits of occupation fluctuated with climatic changes, but both Australia and the Americas had been occupied. There is evidence of a great number of local cultures at this period, each, presumably, representing an adjustment to a particular ecology. It may be assumed that the world's population was small and that each local group was in fairly stable adjustment to the food supply within its range. Since local cultures were increasingly adjusted to local environments, there was probably little large scale migration, except in areas where climatic change made it desirable. In spite of the relatively small population, there seems to have been great diversity in physical type,understandable on the basis of life in small, inbred communities.

The economy of this period included fishing in favored localities, but dwellers in forest and semi-arid regions were predominantly gatherers of vegetable foods. Hunting economy predominated in northern Eurasia, including the steppes, in the African plateau, and in the Northern American Plains. The stage was thus set for the next step in cultural development, the invention of agriculture, followed by the domestication of animals. Agriculture was, understandably, invented by groups who already depended primarily on vegetable foods. Its early appearance in several semi-arid areas in both the Old and New Worlds stems from the necessity for people living in such regions to depend heavily on vegetable foods, especially seeds.

In the Old World, there appear to have been two principal centers for the domestication of plants and animals. The more important, in Southwest Asia and adjoining sections of Africa, specialized in grains and legumes, *i.e.* seed crops. In this region, the ox, ass, sheep, and goat were also domesticated. This region became ancestral to all the higher civilizations of the Old World, with the possible exception of China. Even here, its contribution was considerable. There appears to have been a second center of domestication in Southeast Asia based upon jungle crops, among which, banana, breadfruit, yam, and taro were most important. Associated animals were the pig and chicken. This Southeast Asiatic center was not responsible for the development of any urban cultures, but strongly influenced Oceania and parts of India and may have exerted some influence northward into southern China. Since its crops were dependent upon tropical conditions, its possible extensions were strictly limited.

China presents a puzzle which cannot be solved until we know much more about the archaeology of the southern part of the country. Russian researches into plant origins assign a large number of domestic plants to this region, but only two of these, soy bean and millet, seem adequate for the support of an agricultural population. The appearance of rice during the Neolithic period in northern China also presents an interesting problem, since this plan seems to have been domesticated in India and is poorly suited to the north Chinese environment.

The development of food raising in various Eurasiatic centers cut off further development of most of the food-gathering and hunting cultures. With the assured food supply which agriculture gave, groups which had adopted it could increase rapidly and take up more and more of the food gatherers' territory. The only regions which were safe from this encroachment were those in which the agriculturalists' crops could not be grown. In Eurasia, this comprised the whole boreal forest zone and northern steppes. Here, a hunting and fishing culture was able to survive, perfecting its adjustment to a difficult environment and, finally, adding to its original equipment of Upper Paleolithic type such appliances as the sled, snow shoe, and ski.

In Africa, the cattle which formed part of the Southwest Asiatic food raising complex could adapt to the conditions of the African plateau and, with the dairying techniques, made possible settlement of

this region on a small village basis. However, the crops of the Southwest Asiatic center, even those of its Abyssinian subcenter, could not be raised in Equatorial Africa. The only exception to this seems to have been millet, one variety of which was domesticated in Abyssinia. As a result, the development of higher culture in tropical Africa was delayed until relatively late times. In spite of long contact with Egypt and, less directly, with the Mediterranean hearth of civilization, tropical Africa lagged far behind most of the Old World. This was because it had no food supply adequate to support a large settled population until the introduction of Southeast Asiatic and American food plants.

In spite of these limitations, the basic patterns of village life, which we are accustomed to call Neolithic, spread from Southwestern Asia over most of Europe and North Africa. To the eastward, they spread into India, but there encountered competing influences from the Southeast Asiatic center. While the Southwest Asiatic patterns seem to have established themselves almost *in toto* in the Indus valley and adjoining regions suited to grain raising, they failed to penetrate the eastern and southern parts of the peninsula. Eventually, elements from the two sources fused to produce Hindu culture which owes some of its most striking features, such as the caste system, to the re-working of Southeast Asiatic elements.

In the steppes, the intrusion of Southwest Asiatic village patterns was limited by climatic factors, important among which were the long range fluctuations in rainfall. Here, as in Africa, cattle proved more adaptable than crops and the result was the emergence of a dairying economy eked out by incidental cultivation. It was this economy which was carried westward into Europe by migrants during the later Neolithic and Early Bronze Age. This dairying culture shows many interesting similarities to that developed in the African plateau. It is not to be confused with the full nomadism of later steppe peoples such as the Tartars. This last was a late and special development based upon a fusion of certain elements from the dairying culture and from the boreal forest culture.

The origins of Chinese culture present a puzzle. The earliest Neolithic remains indicate a culture which seems to have many boreal forest elements, plus millet agriculture, and with the dog and pig as the only domestic animals. Toward the close of the Neolithic, a few elements of Western origin, notably painted pottery, appear, while with the emergence of the Bronze Age Shang dynasty there are still more, including the cultivation of wheat, and the whole complex of southwest Asiatic animals except the ass. However, dairying is still lacking and the culture, as a whole, has a strong local character which makes it appear as though the southwest Asiatic elements were due to diffusion rather than actual invasion from the west.

In Southwestern Asia itself, progressive desiccation resulted in the development of still another type of culture. As the areas in which agriculture was possible shrank, the regions between came to be occupied by pastoral nomads who existed in a symbiotic relation with the settled villagers. In sharp distinction to the later nomads of the steppes, these people did not develop a self-sufficient economy. Since they were in contact with settled agriculturalists throughout their history, they adapted to this and became dependent upon the settled people for practically all their material culture and even for the bread which was their principal food.

Turning to the New World, it must be admitted that our information on the earliest settlement of America is still woefully inadequate. The problem turns on two points: what were the first Eurasiatic cultures to reach the Bering Strait region, and what were the climatic conditions in this region at various times? Until these questions have been settled, we cannot get far. There can be very little question that cultures of the boreal forest type were carried across the Strait into the New World, but

it remains to be seen whether these were the earliest. Eastern Asia is far outside the known distribution of the easily identified Biface cultures, although a few doubtful Biface implements have been reported from western China. If Lower Paleolithic people reached the neighborhood of the Strait, they presumably had cultures of the Pebble Axe type or possibly some variant of the Large Flake culture. The Northeastern limits of both of these are still unknown. According to Dr. de Terra, the oldest implements from Mexico do show East Asiatic parallels (Dr. He mut de Terra, personal communication), although they show no relation to the well-known Folsom and Yuman types found farther north.

It is becoming increasingly clear that there have been considerable fluctuations of climate in the Bering Strait region during and since the Pleistocene. Not only did a number of Asiatic temperate climate forms, such as the bison, enter America from Asia during the Pleistocene, but, in quite recent times, prairies seem to have extended right up to the Strait on the American side. The not infrequent changes in sea level which took place during the Pleistocene must also be reckoned with, since the closing of the Strait must have meant a much warmer climate to the south of it than we have at present. It seems quite possible, on all grounds, that man entered the American continent at least as early as the last interglacial, but if his culture was of Pebble Axe type, it will be difficult to prove it. The implements of this culture are crude enough to be taken for rejects unless they are found in an unmixed site under test conditions.

What we do know of early North American cultures is that even by Folsom times there were two distinct types recognizable. One of these, represented by Folsom and Yuman, with eastern derivatives, seems to have followed a big game hunting economy. The other, represented by a series of much less spectacular cultures, seems to have subsisted on small game and vegetable foods. This second culture type has been most clearly identified in the southern Rocky Mountain plateau. If these two cultures do represent the earliest types in America, one might anticipate that it would be the small game, vegetable food economy which would be carried southward by migrants. The great game herds, on which the Folsom-Yuman hunters seem to have depended, did not penetrate far into Mexico.

If the dates assigned, even to Folsom, are correct, the settlement of America must have been followed by a long period of something approaching cultural stasis, relieved only by periodic invasions of new peoples coming across the straits. However, as the boreal culture took more and more adequate form in the Old World, there would have been less and less tendency for such migrants to spread southward beyond the limits of the ecology to which their culture was adapted. The next stage in the development of the American cultures was set in train here, as in the Old World, by the rise of food raising.

It has already been said that only people who were already primarily dependent upon wild vegetable foods would be likely to develop agriculture. Since the only really good hunting territory in the New World was the Great Plains of North America and, possibly, parts of the boreal forest, most of the early American settlers fulfilled this requirement. While there seem to have been certain centers for intensive plant domestication, there were also, if the botanists are to be believed, many domestications of single species in particular regions. Certainly, there was a tremendous amount of diffusion of domesticated plants from their points of origin, the wide distribution of maize being a case in point. The American food-raising economy was hampered by a lack of adequate domestic animals and a consequent lack of dairy products. To replace these, a number of high protein crops were domesticated and diffused. The writer believes that a check on the emergent centers of higher civilization in the New World would show that these were correlated with the establishment, as a result of plant diffu-

sion from various directions, of a combination of crops which would provide a balanced ration.

At present, it seems as though the first center in which this was achieved was the Andean region. Extensive developments in technology, art and social inventions followed rapidly, then stabilized and continued with only minor changes until the Spanish conquest. The spread of this culture to the east was inhibited by climatic factors. How far it spread to the north and whether it contributed to the emergence of the high meso-American cultures is still a moot point. However, we know that there was a second center of civilization in Meso-America which influenced both the Southwestern and Southeastern United States. The rise of higher cultures in both these United States centers was exceedingly late and their potentialities were still only partially exploited when the Europeans arrived. In South America, the penetration of the jungle and the establishment of the characteristic jungle technology seems to have been post-agricultural, but the formidable environment prevented development of high cultures.

It is hoped that the foregoing may provide a rough outline for the understanding of the origins and inter-relations of some of the principal lines of culture development. Much has, of necessity, been omitted especially in the treatment of the New World, where conditions are well known to the present audience.

SECTION OF PHYSICS AND CHEMISTRY

A DISSIPATION MECHANISM IN GAS FLOWS AND SIMILAR PHYSICAL SYSTEMS

By PAUL LIEBER*

Introduction

The behavior of systems with many degrees of freedom, which obey the laws of classical mechanics, can be predicted in principle by integrating the equations of motion of the system that are constructed in accordance with Newton's laws. Although the mathematical difficulties become virtually intractable for such a procedure, the procedure, nevertheless, remains valid, in principle, from a physical point of view. This implies that all gas phenomena governed by the classical laws of mechanics, such as the dissipation of mass flow energy of a gas, in principle, are completely determined by Newtonian mechanics. The concept of probability, on which statistical mechanics and the kinetic theory of gases are based, has been used in conjunction with Newtonian mechanics as an expedient for predicting quantitatively the behavior of mechanical systems with a very large number of degrees of freedom. The kinetic theory of gases, which is concerned, in general, with phenomena of gases that are not in a steady state (such as viscosity, heat conduction, diffusion, etc.), leads to the problem of calculating a distribution function that must satisfy the Boltzmann integral-differential equation. In this very general theory, the mechanics is concealed, to a large extent, by the statistical laws. It, therefore, becomes very difficult (if at all possible) to detect or discover by means of the kinetic theory the mechanisms that control specific phenomena of gases that are not in a steady state, and the extent to which they can be explained by considering only a small number of degrees of freedom. The general validity of a Newtonian description of a gas on a molecular scale, discussed above, suggests that mechanisms which control such gas phenomena may exist in systems consisting of a small, as well as of a large number of degrees of freedom. Such systems may, therefore, be completely de-

* Department of Aeronautical Engineering, Brooklyn Polytechnic Institute, Brooklyn, N. Y. This paper, illustrated with lantern slides, was presented at the meeting of the Section on February 1, 1949.

scribed, quantitatively, by the Newtonian laws of motion without recourse to the concept of probability. In such cases, the mechanisms are not determined or modified by statistical laws, but are completely determined by purely mechanical considerations.

A dissipation mechanism,* for transforming mass flow (mechanical) energy into non-mechanical energy of a gas and similar systems, is proposed and investigated here. The procedure is based on a consideration of a small number of degrees of freedom contained within a system consisting of a very large number of degrees of freedom. This mechanism, which is completely determined by mechanical considerations, explains *how* and *why* mass flow energy is dissipated in a gas. It is shown that between the components (molecules) that transfer momentum only by collisions, the finite extent of these components is a necessary condition for the mechanism to exist. In systems where central (position) forces act as well, this condition is no longer necessary, and the dissipation mechanism does not depend upon momentum transfer by collisions. The mechanism is found to be, in general, reversible; that is, it is shown that it can also transform non-mechanical energy into mechanical energy. This reversibility does not detract from its importance, as it still explains the mechanics of energy dissipation. It is proven however, without the use of the concept of probability, that, under special conditions, mechanical energy once dissipated by the mechanism cannot be completely recovered at any subsequent time.

The problem of *how much* mass flow energy is dissipated or recovered by the mechanism, in a system with a large number of degrees of freedom, not in a steady state, is treated by applying the concept of probability directly to expressions for the dissipation energy before and after a set of typical binary collisions. These expressions are obtained by considering the dissipation mechanism for a typical binary collision.

The dissipation mechanism corresponding to ternary and higher order collisions are also investigated. These collisions, however, are not treated statistically, since they are much less probable than binary collisions. Accordingly, the concept of probability is here used axiomatically for a quantitative evaluation of macroscopic phenomena which are determined mechanically and on a molecular scale by the dissipation mechanism.

It is shown that the dissipation mechanism proposed here adds insight directed toward a physical understanding of shock-wave and some boundary layer phenomena on a molecular and macroscopic scale of observation. An outline of a theory based upon this mechanism and developed for calculating compression and expansion waves in steady sub-sonic and super-sonic flows is given. This work was sponsored by the Office of Naval Research, United States Navy.

Theory

This paper presents the investigation of a dissipation mechanism proposed for dissipating mechanical (macroscopic) energy in mechanical systems consisting of a very large number of degrees of freedom which are contained and, in general, arbitrarily distributed, in a rectangular Cartesian space x, y, z. This mechanism provides a physical understanding on a molecular scale of the mechanics of the specific operations between molecules which transform mechanical energy into dissipation energy. The physical understanding which is acquired on a molecular scale, by considering a small number of degrees of freedom of a mechanical system, is then extended to a macroscopic scale. This is done by first considering the mean values of specific functions (determined by the mechanism) of parameters that describe the states of two particles immediately before and after a typical binary collision. Then, the concept of probability is applied axiomatically

* This mechanism was initially described by the author in a manuscript submitted to the Journal of Applied Physics in January 1948.

toward evaluating and interpreting the mean values of these functions. The mean values of the functions of state so obtained are essentially the most probable values of the corresponding macroscopic functions of state of the system. It is, therefore, important to define carefully the macroscopic functions of state that are considered here in terms of the parameters which describe the state of the system on a molecular scale. A number of these definitions will be found equivalent to those used in the kinetic theory of gases. Others have been suggested by, and stem from, the dissipation mechanism. In general, the systems considered here are not in a steady state, and the definition for the mean value of any function of state of a system refers to its instantaneous value. Unless otherwise stated, it is assumed that the particles or molecules of the systems considered here are perfectly elastic, finite, of equal mass, that they transfer momentum only by collision, and that their only form of energy is kinetic. The dissipation mechanism is not inherently restricted to systems with components that transfer momentum only by collision. It also exists in systems consisting of components that transfer momenta by means of central (position) forces. However, the dissipation mechanism, as it pertains to these systems, is not considered here in any detail.

Mass Density. The mass density, ρ, of a system contained in a finite volume element λ enclosing a point x, y, z, is the limit of the quantity $\frac{mn}{\lambda}$, where λ is sufficiently large compared to the dimensions of the particles and their mean free path. This choice is made in order to ensure a virtually homogenous mass distribution within the element. Furthermore, n is the number of particles contained in λ, m is the mass of a single particle, and M is the total mass enclosed by λ.

Mass Flow Velocity. The Mass flow velocity, $\bar{U}$, of a system of n particles contained in a volume element λ is the mean value of the resultant velocities of each of these particles. Strictly speaking, this definition of mass flow velocity pertains to the system contained in volume element λ enclosing the point x, y, z. However, if λ can be taken sufficiently small, then, for all practical purposes, this may be considered as a definition for the mass flow velocity at the point x, y, z, as well. From this definition, it follows that the mass flow velocity in region λ depends only upon the velocity components of the individual particles contained in λ that are parallel to the mass flow velocity.

Mass Flow Momentum. The mass flow momentum, H, of a system contained in volume element λ is the product of the total mass, M, and the mass flow velocity of the system.

Principal Velocity Component of a Particle. The velocity component of a particle contained in a volume element λ which has the direction of the mass flow velocity of the system is called the principal velocity component of the particle. The direction of mass flow is called the *principal direction* of motion of the particles of the system.

Longitudinal Velocity Component of a Particle. A velocity component of a particle contained in a volume element λ which has a direction opposite to the principal direction of motion, is called a longitudinal velocity component of the particle.

Tranverse Velocity Component of a Particle. A velocity component of a particle contained in a volume element λ that is perpendicular to the mass flow of the system is called a transverse velocity component of the particle.

The mechanical energy, E_m, of a system of particles contained in a volume element, is the product of $M/2$ and the mean value of the square of the principal velocity components of the individual particles of the system. It follows from this definition that only the principal velocity components of the particles contribute to the mechanical (mass flow) energy of the system. The

kinetic energy determined by the velocity components of the particles in the longitudinal and transverse directions are designated here as E_L, and E_T, respectively. Accordingly, E_L and E_T represent the dissipation energy of the system.

The Dissipation Mechanism. Consider a rectangular Cartesian space x, y, z, which contains a gas consisting of discrete and finite elastic particles of equal mass. These particles are arbitrarily distributed in space with a velocity distribution, such that, the instantaneous mass flow velocity of the system contained in a finite volume element λ has everywhere the direction of the positive x axis. Accordingly, the positive x axis is everywhere the principal direction of motion of the gas particles. This system can be briefly described as a three dimensional, non-steady, gas flow, in which the mass flow has everywhere the direction of the positive x axis.

Consider any two particles of this gas enclosed by a volume element λ, each having transverse and principal velocity components. Only the principal velocity components of each particle contribute to the mass flow energy in region λ. Accordingly, any mechanism which can decrease the kinetic energy of the principal velocity components, and consequently, increase the kinetic energy of the transverse or the longitudinal components, is a mechanism for dissipating mass flow energy in any region λ. It will be shown that any collision between two such particles is a dissipation mechanism, provided the angle θ formed by the line connecting their centers and the principal direction is different from zero, or integral multiples of π and $\frac{\pi}{2}$. Under suitable conditions, it is found that this mechanism can also transform dissipation energy into mass flow energy, and it is therefore reversible in this sense. This, however, does not detract from its significance, since the mechanism still explains the mechanics of energy dissipation on a molecular scale without recourse to a concept of probability.

In the following analysis, it is assumed that the flow just described is two dimensional, and that the state of the gas flow is independent of the space variable z. This is done for mathematical expediency, since the salient properties of the dissipation mechanism can still be retained, and mathematically described by the analysis.

Analysis. At a given time t_0, consider a collision between any two particles, 1 and 2, of a two dimensional gas flow contained in a volume element λ. Let u_i and v_i be the velocity components, of particle i before collision, which are parallel to the x and y axis respectively. Let u_i' and v_i' be the corresponding velocity components of particle i after collision. The index i assumes the value of 1 and 2. Using the principles for the conservation of Energy and Momentum, the following equations are obtained.

$$v_1' = -u_1 \cos\varphi \sin\varphi + v_1 \sin^2\varphi + u_2 \sin\varphi \cos\varphi + v_2 \cos^2\varphi \tag{1}$$

$$v_2' = -u_2 \cos\varphi \sin\varphi + v_2 \sin^2\varphi + u_1 \sin\varphi \cos\varphi + v_1 \cos^2\varphi.$$

$$u_1' = u_2 \sin^2\varphi + u_1 \cos^2\varphi + \cos\varphi \sin\varphi\,(v_2 - v_1) \tag{2}$$

$$u_2' = u_1 \sin^2\varphi + u_2 \cos^2\varphi + \cos\varphi \sin\varphi\,(v_1 - v_2)$$

The angle φ is formed (FIGURE 1) by the perpendicular to the line connecting the centers of the particles and the (principal direction) positive x axis.

It is clear that $v_1' = v_2' = 0$ is a necessary condition that, after a binary collision, all the energy of the particles be in the form of mechanical energy.

Setting $v_1' = v_2' = 0$ in EQUATION 1 and then adding, shows that $v_1 = -v_2$ is a necessary condition for complete recovery of mechanical energy. This result will later be used to prove an interesting theorem. Another condition which is necessary for

complete recovery is that both u_1' and u_2' be positive.

The transverse energy E_T', after a binary collision between particles 1 and 2, is

$$\begin{aligned} E_T' &= \tfrac{1}{2}m(v_1'^2 + v_2'^2) \\ &= \tfrac{1}{2}m\{(u_1 - u_2)^2 + 2v_1v_2\}\frac{\sin^2 2\varphi}{2} \\ &+ m\{-u_1v_1 - u_2v_2 + v_1u_2 + u_1v_2\} \\ &\sin^2\varphi \sin 2\varphi + \tfrac{1}{2}m\{-u_1v_2 - u_2v_1 \\ &+ u_2v_2 + u_1v_1\}\sin 2\varphi \\ &+ \tfrac{1}{2}m(v_1^2 + v_2^2)\left(1 - \frac{\sin^2 2\varphi}{2}\right) \end{aligned} \tag{3}$$

EQUATION 3 relates the transverse energies before and after a collision. It is seen from this equation that a term which can contribute significantly to an increase in the transverse energy, and consequently

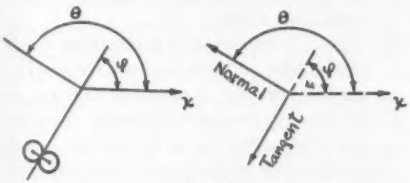

FIGURE 1

decrease the mechanical energy after collision, is

$$\tfrac{1}{2}m(u_1 - u_2)^2 \frac{\sin^2 2\varphi}{2}.$$

When the subscripts P or L are attached to a velocity component u_i, they indicate that it is a principal or a longitudinal component respectively. Accordingly, the general expressions for the mechanical and longitudinal energies of two particles after collision are

$E_M' = \tfrac{1}{2}m(u_{P1}'^2 + u_{P2}'^2)$ and $E_L' = \tfrac{1}{2}m(u_{L1}'^2 + u_{L2}'^2)$

respectively. Whether a velocity component u_i' is principal or longitudinal is determined by EQUATION 2. It is noted that when u_P is finite then u_{Li} must be zero.

The following conclusions follow from EQUATIONS 1, 2, and 3.

(a) A binary collision is a dissipation mechanism, provided that the collision angle φ is different from zero or integral multiples of π and $\frac{\pi}{2}$. This mechanism is purely mechanical in the sense that it is completely determined by Newtonian mechanics without recourse to a probability concept. This is a natural result of the fact that it is determined by a few degrees of freedom.

(b) If u_1 and u_2 are both positive, then a decrease of mechanical energy implies a corresponding increase of transverse energy. That is, under these conditions mechanical energy cannot be directly transferred to longitudinal energy. Conversely, if u_1 and u_2 are positive, then an increase in transverse energy implies an equivalent decrease in mechanical energy.

(c) If u_1 and u_2 are both negative, then longitudinal energy cannot be directly transferred to mechanical energy by collisions. Items (b) and (c) follow directly from EQUATION 2.

(d) If u_1 and u_2 are opposite in sign, then a direct transfer between longitudinal and mechanical energy is possible only under special conditions.

The concepts used to determine, on a molecular scale, the dissipation mechanism of the mechanical systems considered above, also apply to physical systems consisting of components subjected to position (central) forces. In such cases, however, collisions are no longer necessary for the mechanism to exist. The mechanism described here is also inherent in ternary and higher order collisions. This follows, since these higher order collisions consist of one or more sets of binary collisions, to each of which the above analysis is applicable. The mechanism is also inherent in systems consisting of finite particles with unequal masses.

Macroscopic Functions of State-Energy Dissipation by Many Degrees of Freedom

In order to calculate the amount of energy dissipated or recovered by the mechanism

in a non-steady gas, it becomes necessary to use a concept of probability. Thus, by using EQUATIONS 1, 2, and 3, the mean values of the velocity components, dissipation energy, and the mechanical energy of two sets of particles that had been engaged in simultaneous binary collisions can be calculated. The mean values of these functions are considered here, since the mean value of any macroscopic function of state is the most probable value of the function. Upon considering many particles that are simultaneously engaged in *binary* collisions, we can calculate the mean value of the transverse dissipation energy resulting from these collisions. Using EQUATION 3, we obtain

$$\tfrac{1}{2}\rho\lambda\overline{(v_1'^2 + v_2'^2)} = \tfrac{1}{2}\rho\lambda\overline{(u_1 - u_2)^2}\,\overline{\frac{\sin^2 2\varphi}{2}} + \tfrac{1}{2}\rho\lambda\overline{(v_1^2 + v_2^2)} - \tfrac{1}{2}\rho\lambda\overline{(v_1^2 + v_2^2)} \quad (4)$$
$$\cdot\,\overline{\frac{\sin^2 2\varphi}{2}} + \tfrac{1}{2}\rho\lambda\overline{(v_1^2 + v_2^2)}$$

non colliding particles. The expressions for the mean values of the velocity components u_1' and u_2' are:

$$\begin{aligned} \overline{u_1^1} &= \overline{u_2}\,\overline{\sin^2\varphi} + \overline{u_1}\,\overline{\cos^2\varphi} \\ \overline{u_2^1} &= \overline{u_1}\,\overline{\sin^2\varphi} + \overline{u_2}\,\overline{\cos^2\varphi} \end{aligned} \quad (5)$$

When a bar is placed over a quantity it indicates the mean value of the quantity. In calculating (4) and (5) from EQUATIONS 2 and 3, it is assumed that the statistical distribution of the transverse velocity components is completely symmetrical and that φ is statistically independent of all the velocity components. EQUATIONS 4 and 5 can be used for calculating the effect of simultaneous binary collisions, between two sets of particles 1 and 2 contained in a region λ, upon the change of mechanical energy in the region, with time. The time measure used here is the interval between successive sets of simultaneous collisions.

Using EQUATIONS 4 and 5 it is possible to deduce the following conclusions:

(e) If a system with a sufficiently large mass flow velocity $\bar{u}_1 > 0$, interacts through a set of simultaneous binary collisions with a similar system having a mass flow velocity $\bar{u}_2 > 0$ where $\bar{u}_2 \ll \bar{u}_1$, then the mechanism transforms some mass flow energy into transverse energy. The decrease in mass flow energy is proportional to the quantity $\overline{(u_1 - u_2)^2}$. This clearly shows the relation between compressibility and dissipation that is characteristic of compression shock waves.

(f) In general, there exists a value for the quantity $\overline{(u_1 - u_2)^2}$ causing an increase of dissipation energy, and a decrease of mass flow energy sufficiently large, so that subsequent interaction between systems 1 and 2 causes an *increase* in mass flow energy.

(g) Item (f) implies the interesting result that under suitable and not very stringent conditions, the probability for an increase in mechanical energy (statistical asymmetry) is a *maximum*. Such phenomena have actually been observed in high speed gas flows; *i.e.*, expansion waves following compression shock waves.[2]

The Intrinsic Mechanical Irreversibility of The Dissipation Mechanism in Some Physical Systems

Consider a gas in which at some time, $t =, t_0$ all the energy of the system is mechanical energy; that is, the resultant velocity of all the particles is in the principal direction of motion. A collision between any of these particles will dissipate some of the mechanical energy, and thereby impart to them a transverse velocity component. Since it was shown earlier that a necessary condition for complete recovery of mechanical energy of two such particles is $v_1 = -v_2$, it follows that at no subsequent time is it possible for the gas to recover by collisions all of its mechanical energy. The proof to this theorem is obtained by showing that

some particles of the system which have transverse components cannot satisfy the condition necessary for a complete recovery. Accordingly, it can be proven, *on purely mechanical grounds*, that in some physical systems the dissipation mechanism is irreversible on a macroscopic scale.

Shock Waves and Boundary Layers in Gas Flows

Both compression shock waves and boundary layers are phenomena of gases which involve a transformation of mass flow energy into dissipation energy, and are consequently determined by the dissipation mechanism. The progressive development of a shock wave and a boundary layer imply a progressive reduction of mass flow energy. The EQUATION 3 clearly shows that strong compression is a necessary condition for reducing mass flow energy in a gas flow that is not enclosed by a rough boundary. It also shows, however, that it is possible, under suitable conditions, to increase the mass flow energy of the system. This is confirmed by experiments conducted by Ackeret, Feldmann, and Rott,[2] in which strong expansion waves following compression waves had been observed. A theory based upon the dissipation mechanism described here has been developed and used for calculating steady, one dimensional, compressible flows with compression and expansion waves.[1] The results show good qualitative and, in some cases, quantitative agreement with the experiments, referred to previously.

When a gas flow is confined by a rough boundary, then mass flow energy can be dissipated (in the sense considered here) at the boundary by collisions between individual molecules and the rough elements of the boundary which protrude into the gas. Consequently, in such a case, the compressibility of the gas is no longer necessary for increasing the dissipation energy. This picture explains the progressive growth of dissipation energy in a boundary layer as the flow continues along a rough surface. At this time, there is some indication that the dissipation mechanism may be helpful toward understanding and predicting turbulence.

Conclusions

(1) A mechanism for dissipating and recovering mechanical energy in gas flows and similar physical systems is proposed here. It is shown that this mechanism is inherent in a small number of degrees of freedom of such a system and is therefore completely determined by purely mechanical (non-statistical) considerations. It is shown that the mechanism is in general reversible on a molecular scale.

(2) It is shown that in some systems the mechanism is irreversible on a macroscopic scale.

(3) The dissipation mechanism is applied to systems consisting of many degrees of freedom by means of statistical consideration. In so doing, expressions for the mean values of the mechanical and dissipation energies are calculated. These expressions provide a simple explanation for the progressive growth of a shock wave. They also show that under suitable conditions the mechanism can transform dissipation energy into mechanical energy on a macroscopic scale.

(4) The results obtained here pertain to gas flows which have everywhere the same direction. However, the properties of the dissipation mechanism so determined, can be applied to any small region in mass flows which are not thus restricted.*

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1. LIEBER, P. 1949. A statistical theory of one-dimensional gas flows with compression and expansion waves. PIBAL Tech. Rep. No. 136.
2. ACKERET, J., F. FELDMANN & N. ROTT. 1947. Investigation of compression shocks and boundary layer in gases moving at high speed. NACA TM No. 1113.

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CONFERENCE HELD

SECTION OF BIOLOGY

CONFERENCE ON "DEVELOPMENT AND USES OF ANTIMETABOLITES": FEBRUARY 11 AND 12, 1949

The Section of Biology held a Conference on "Development and Uses of Antimetabolites." Doctor D. W. Woolley, The Rockefeller Institute for Medical Research, New York, N. Y., was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, February 11

Morning Session. "Introductory Remarks by the Conference Chairman," D. W. Woolley.

"Biochemical Significance of the Competition between p-Aminobenzoic Acid and the Sulfonamides," by D. D. Woods, Oxford University, England.

"The Utilization of Antimetabolites in the Study of Biochemical Processes in Living Organisms," by W. Shive, University of Texas, Austin, Texas.

Afternoon Session. Chairman, D. D. Woods.

"Investigations on the Selectivity of Action of Antimetabolites," by D. W. Woolley, The Rockefeller Institute for Medical Research, New York, N. Y.

"Ion Antagonism as Related to Antimetabolites," by R. A. MacLeod and E. E. Snell, University of Wisconsin, Madison, Wisconsin.

"Competition between Structurally Similar Steroid Hormones and the Interference with Hormonal Effects by Antivitamins," by R. Hertz and W. W. Tullner, National Cancer Institute, Bethesda, Maryland.

Saturday, February 12

Morning Session. Chairman, W. Shive.

"The Structural Bases of Some Amino Acid Antagonists and Their Microbiological Properties," by K. Dittmer, University of Colorado, Boulder, Colorado.

"Desoxypyridoxine—Observations in 'Acute Pyridoxine Deficiency'," by H. C. Stoerk, Merck Institute for Therapeutic Research, Rahway, N. J.

"Studies on Analogs of Purines and Pyrimidines," by G. H. Hitchings, G. B. Elion, E. A. Falco, and P. B. Russell, The Wellcome Research Laboratories, Tuckahoe, N. Y.

Afternoon Session. Chairman, E. E. Snell.

"Analogs of Pteroylglutamic Acid," by T. H. Jukes, E. L. R. Stokstad, and A. L. Franklin, Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

"Folic Acid Analogs in Lower Animals," by E. D. Goldsmith, M. H. Harnly, R. F. Nigrelli, and S. S. Schreiber, New York University, and New York Aquarium, New York Zoological Society, New York, N. Y.

"Studies of the Action of 4-Aminopteroylglutamic Acid and Its Congeners in Mammals," by F. S. Philips, J. B. Thiersch, and F. C. Ferguson, Sloan-Kettering Institute and Cornell University Medical College, New York, N. Y.

"Folic Acid Antagonists and Experimental Tumors," by C. C. Stock, J. H. Burchenal, J. Biesele, D. Karnofsky, A. E. Moore, and K. Sugiura, Sloan-Kettering Institute, New York, N. Y.

NEW MEMBERS

Elected February 24, 1949

LIFE MEMBERSHIP

Falk, Henry C., M.D., Operative Gynecology. Clinical Professor of Gynecology, New York University Post Graduate School, New York, N. Y.

SUSTAINING MEMBERSHIP

Fremont, Rudolph E., M.D., Internal Medicine. Chief, Cardiovascular Section, Halloran V. A. Hospital, Staten Island, N. Y.

ACTIVE MEMBERSHIP

Argyris, Thomas S., A.B., Physiology, Chemistry. Graduate Assistant, Johns Hopkins University, Baltimore, Md.

Austin, J. Harold, M.D., Biochemistry. Professor of Research Medicine, University of Pennsylvania, Philadelphia, Pa.

Bennett, Mary A., Ph.D., Biochemistry. Research Biochemist, Lankenau Hospital Research Institute, Philadelphia, Pa.

Berardi, Gloria Anne, B.S., Endocrinology, Histology, Physiology. Teaching Fellow, New York University, New York, N. Y.

Brandt, J. Leonard, M.D., Cardiovascular-Renal Physiology. Fellow, Department of Medicine, College of Physicians & Surgeons, New York, N. Y.

Brewer, Nathan R., D.V.M., Ph.D., Veterinary Medicine, Physiology. Lecturer in Physiology and Superintendent of Animal Quarters, University of Chicago, Chicago, Illinois.

Brick, Irving B., M.D., Internal Medicine. Chief, Gastroenterology Clinic, Georgetown University Hospital, Washington, D. C.

Burman, Louis R., D.D.S., Periodontia, Anatomy. Assistant Professor in Periodontia, New York University College of Dentistry, New York, N. Y.

Campbell, Delwin M., D.V.S., Veterinary Medicine, Biology. Editor, Veterinary Medicine Magazine, Chicago, Ill.

Carrigan, Paul T., M.D., Medicine, Biology. Resident in Pathology, New York Medical College, New York, N. Y.

Chalmers, Thomas C., M.D., Internal Medicine. Assistant in Medicine, Harvard Medical School, Boston, Mass.

Cohlan, Sidney Q., M.D., Pediatrics. Pediatric Staff, Beth Israel Hospital, New York, N. Y.

Conroy, Edward A., Ph.D., Organic Chemistry. Research, American Cyanamid Company, Bound Brook, N. J.

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EDITOR'S NEWSNOTES

John B. Calkin, New York, has been appointed Director of the Department of Industrial Cooperation, and Associate Professor of Chemical Engineering at the University of Maine, according to a recent announcement by Dr. Arthur A. Hauck, president of the University.

Professor Lyle Jenness, who has been Acting Director of the Department of Industrial Cooperation, will devote his full time to his duties as head of the Department of Chemical Engineering.